FIG. 1

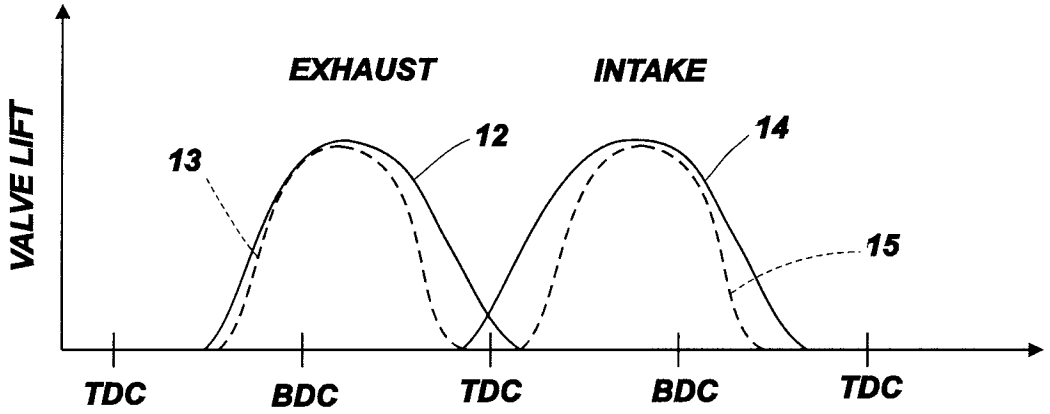

VALVE LIFT
EXHAUST
INTAKE
13
12
14
15
TDC
BDC
TDC
BDC
TDC

FIG. 2

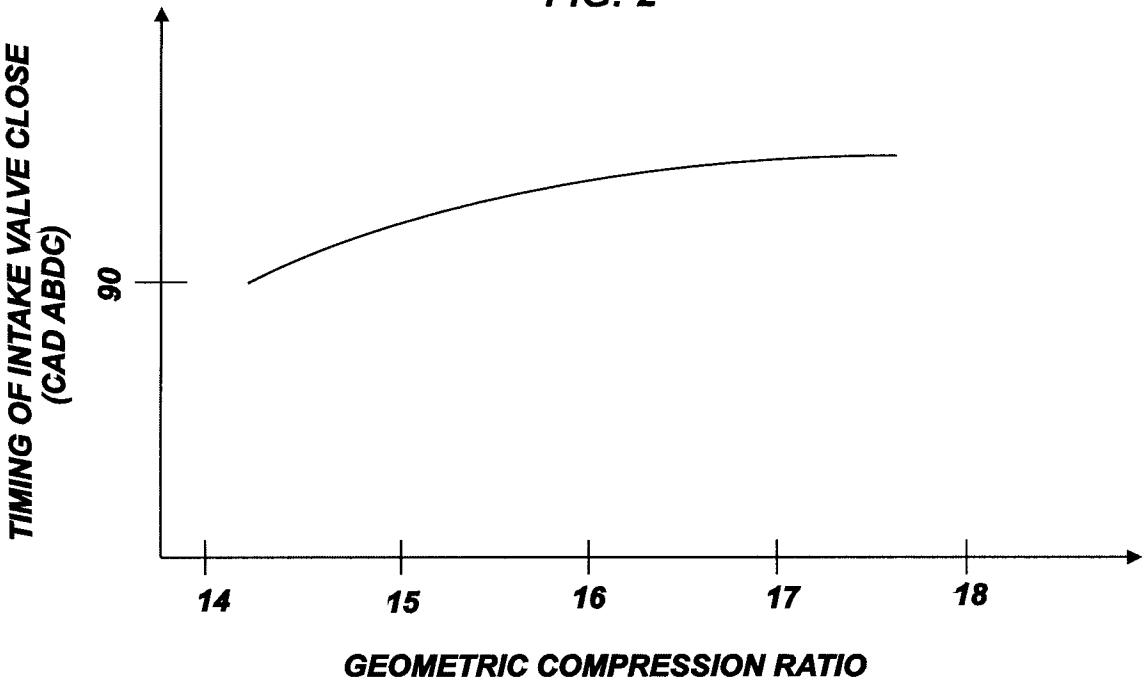

TIMING OF INTAKE VALVE CLOSE
(CAD ABDC)
90
14
15
16
17
18
GEOMETRIC COMPRESSION RATIO

FIG. 3

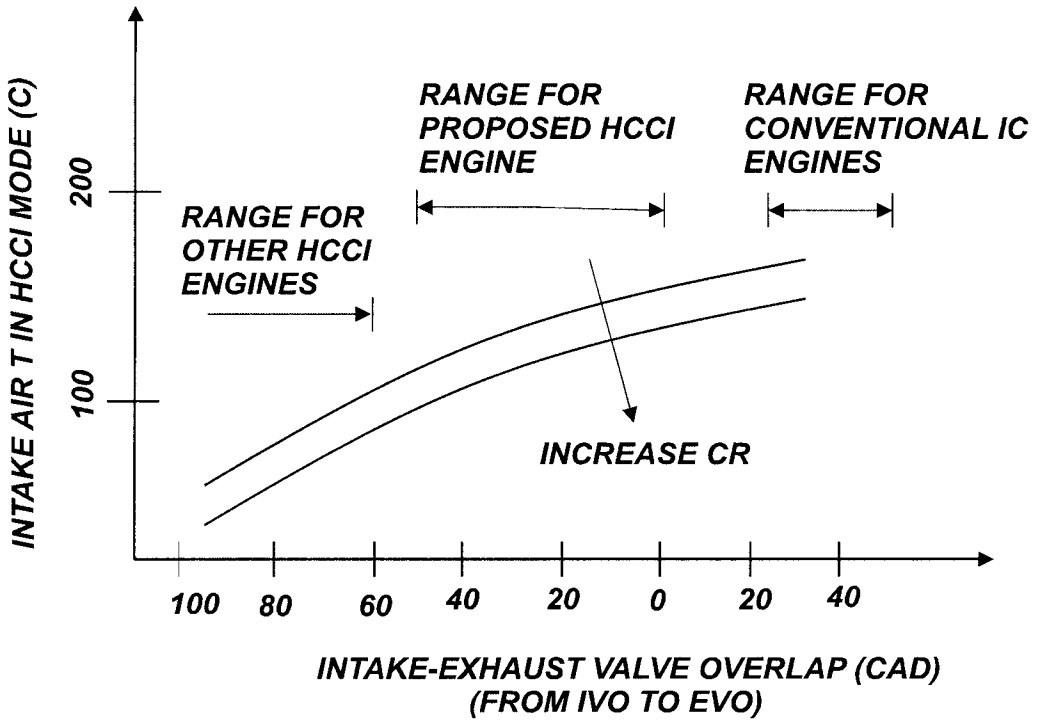

INTAKE AIR T IN HCCI MODE (C)
200
100
RANGE FOR PROPOSED HCCI ENGINE
RANGE FOR CONVENTIONAL IC ENGINES
RANGE FOR OTHER HCCI ENGINES
INCREASE CR
100
80
60
40
20
0
20
40
INTAKE-EXHAUST VALVE OVERLAP (CAD)
(FROM IVO TO EVO)

FIG. 4

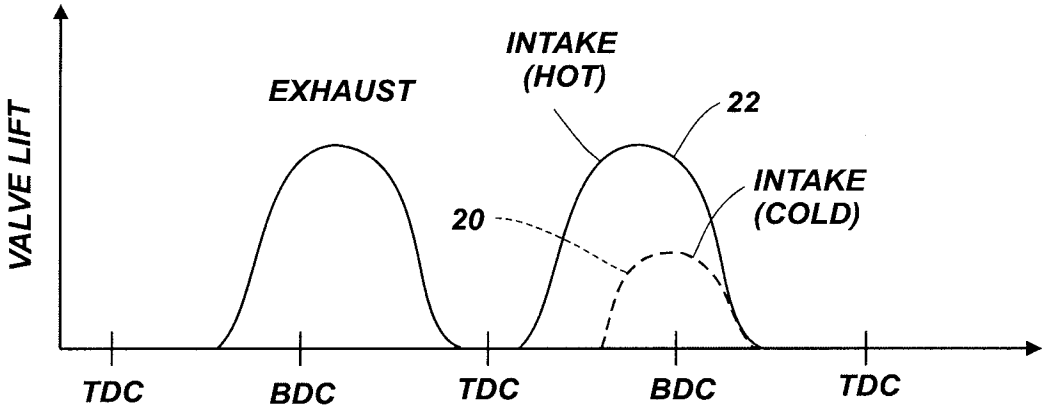

VALVE LIFT
EXHAUST
INTAKE (HOT)
22
INTAKE (COLD)
20
TDC
BDC
TDC
BDC
TDC

FIG. 5(A)

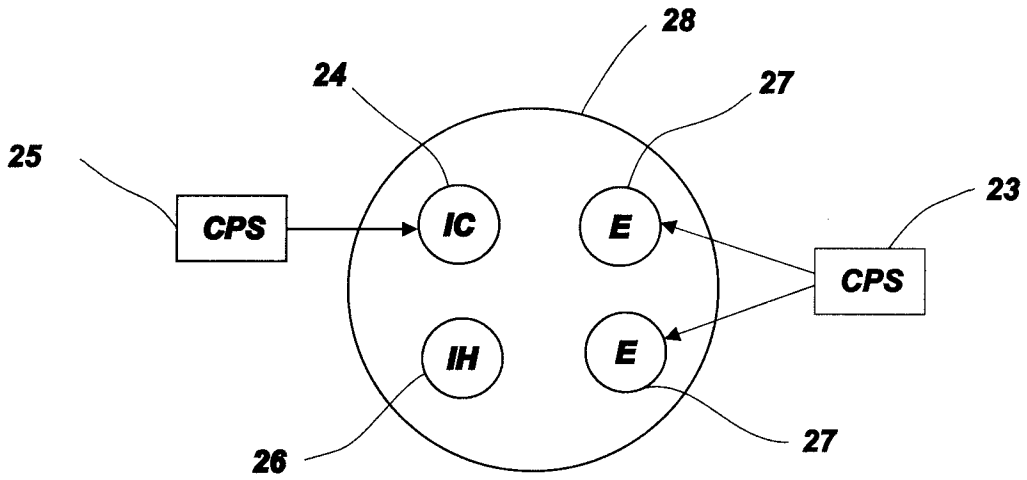
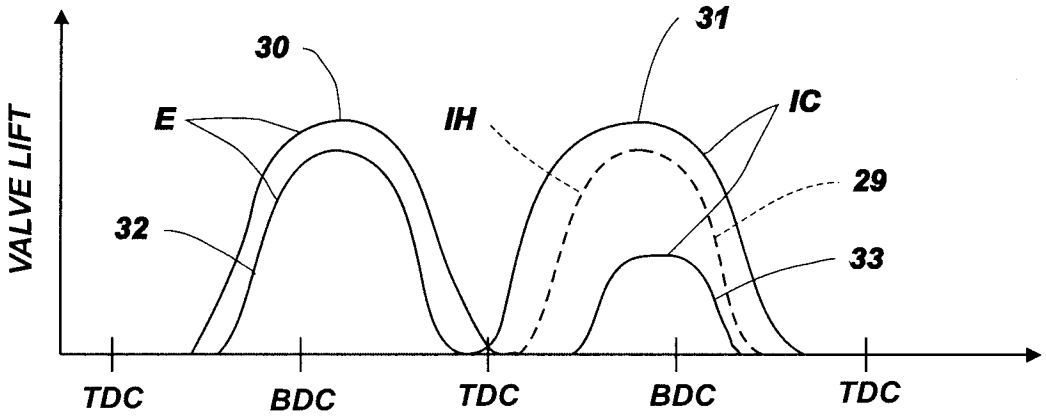

28
24
27
25
CPS
IC
E
23
CPS
IH
E
26
27

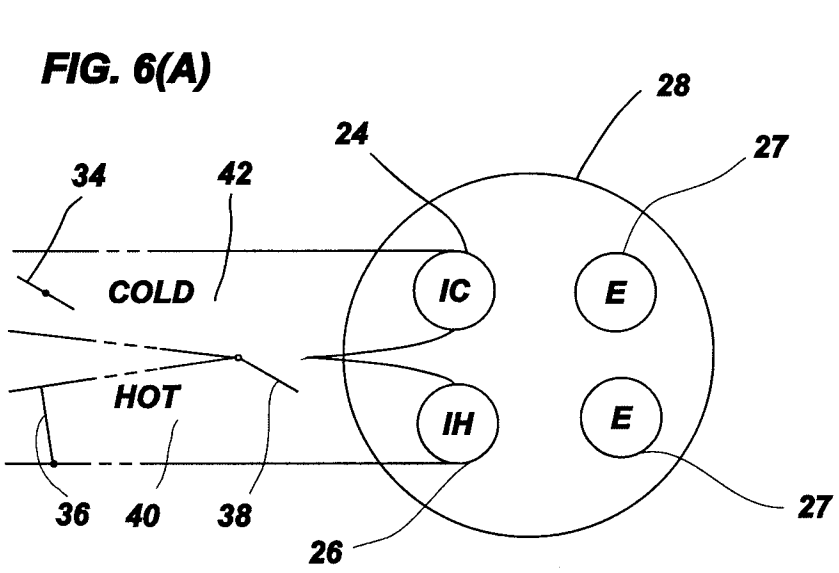
FIG. 5(B)


31
30
IC
E
IH
29
32
33
VALVE LIFT
TDC
BDC
TDC
BDC
TDC

LIFT PROFILE	EVENT LENGTH (CAD)	NORMALIZED VALVE MAX. LIFT	VALVE OPEN TIMING	VALVE CLOSE TIMING
INTAKE IC-OUTER	280 ~ 320	1	0 ~ 15 CAD BTDC	95 ~ 125 CAD ABDC
INTAKE IC-INNER	150 ~ 210	0.3 ~ 0.7	-50 ~ 0 CAD BTDC	25 ~ 45 CAD ABDC
INTAKE IH	170 ~ 210	1	-35 ~ 0 CAD BTDC	25 ~ 45 CAD ABDC
EXHAUST E-OUTER	230 ~ 250	1	50 ~ 70 CAD BBDC	0 ~ 20 CAD ATDC
EXHAUST E-INNER	190 ~ 220	0.8 ~ 0.95	40 ~ 60 CAD BBDC	-35~ 0 CAD ATDC

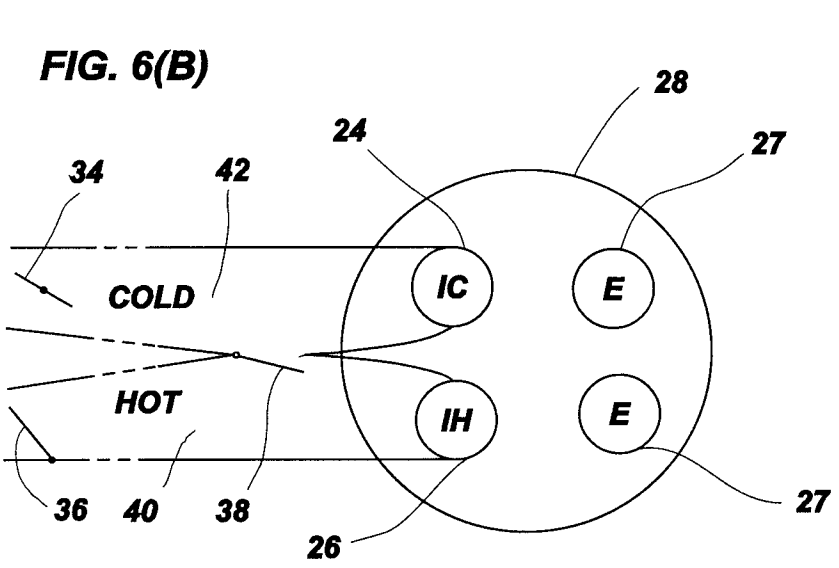
FIG. 5(C)

FIG. 6(A)



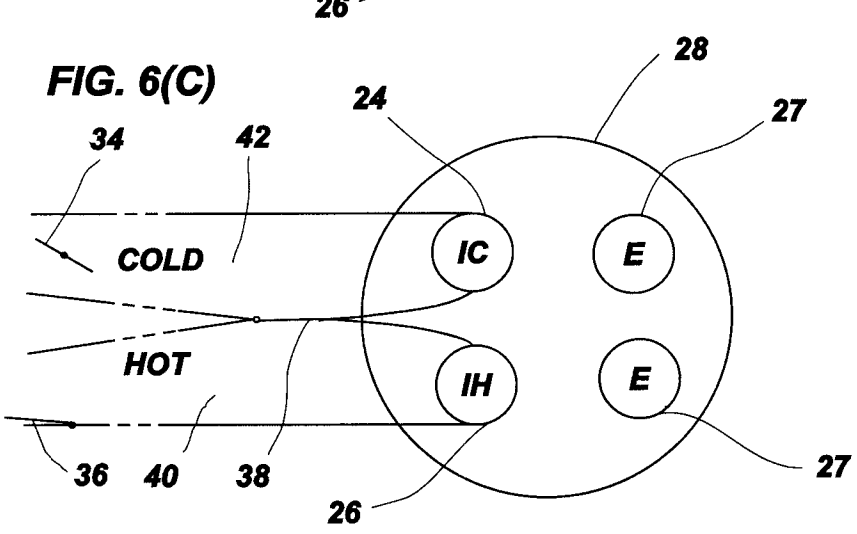
SI MODE	
IC	OUTER PROFILE
E	OUTER PROFILE

FIG. 6(B)



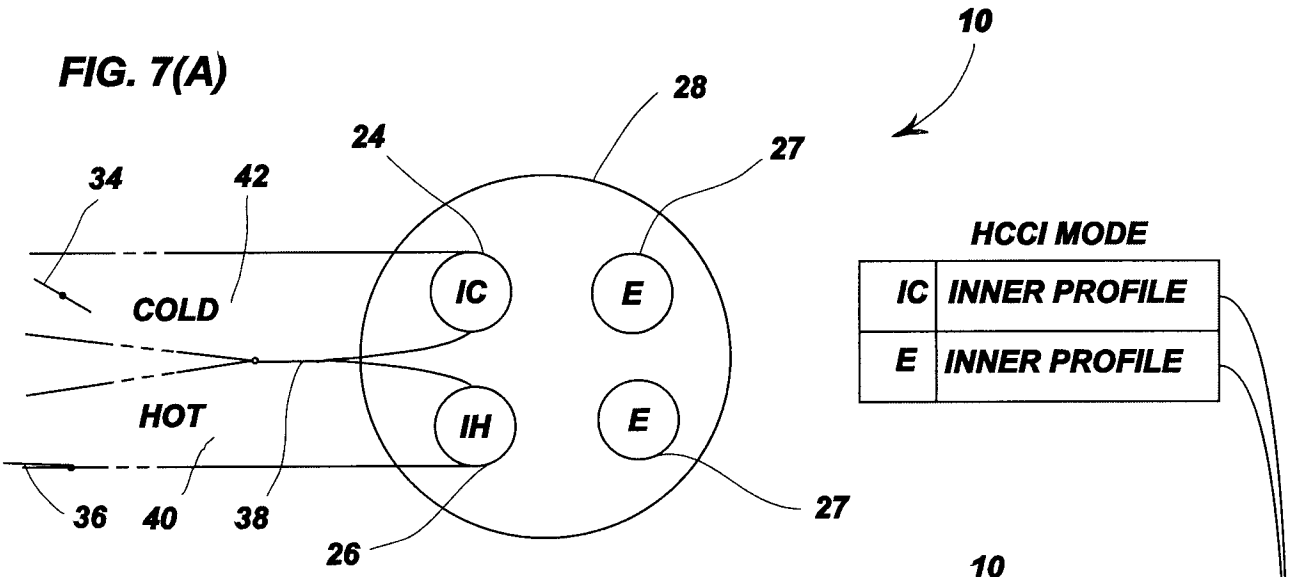
SI MODE	
IC	OUTER PROFILE
E	OUTER PROFILE

FIG. 6(C)



HCCI MODE	
IC	INNER PROFILE
E	INNER PROFILE

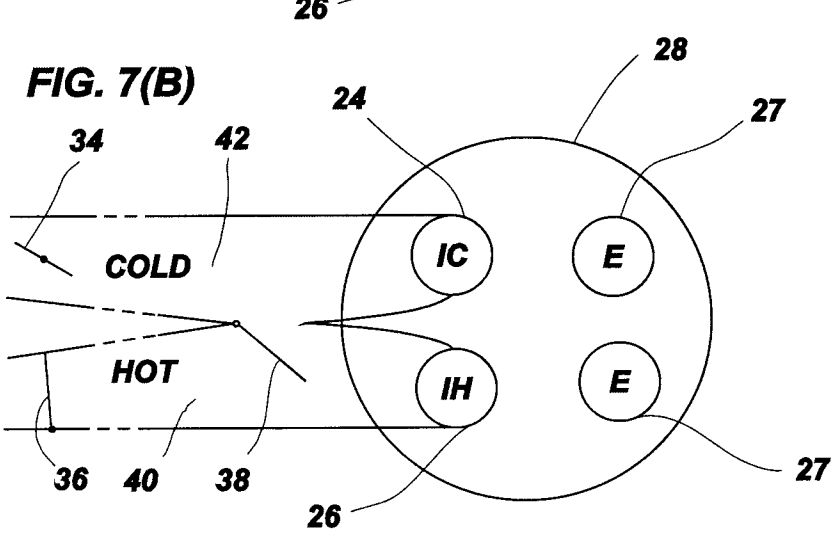
FIG. 7(A)



HCCI MODE

IC	INNER PROFILE
E	INNER PROFILE

FIG. 7(B)



SI MODE

IC	OUTER PROFILE
E	OUTER PROFILE

FIG. 8(A)

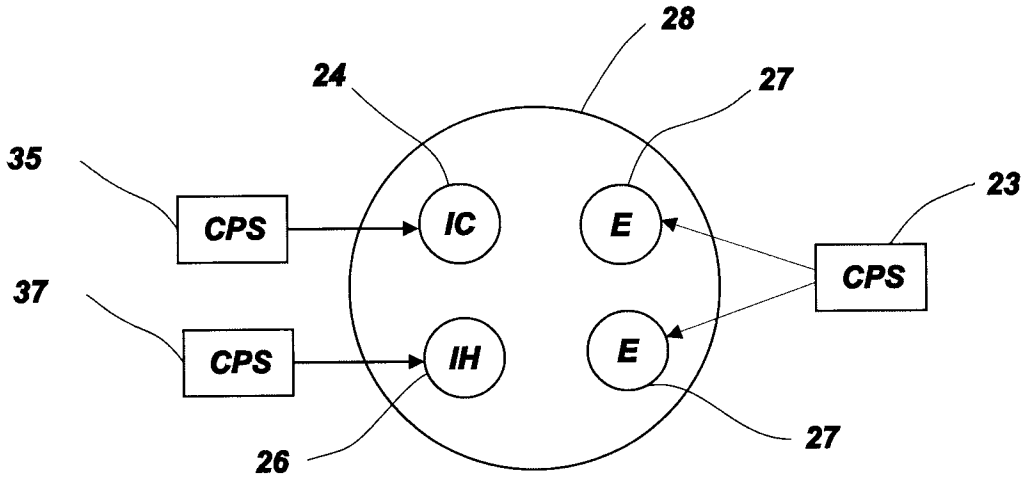
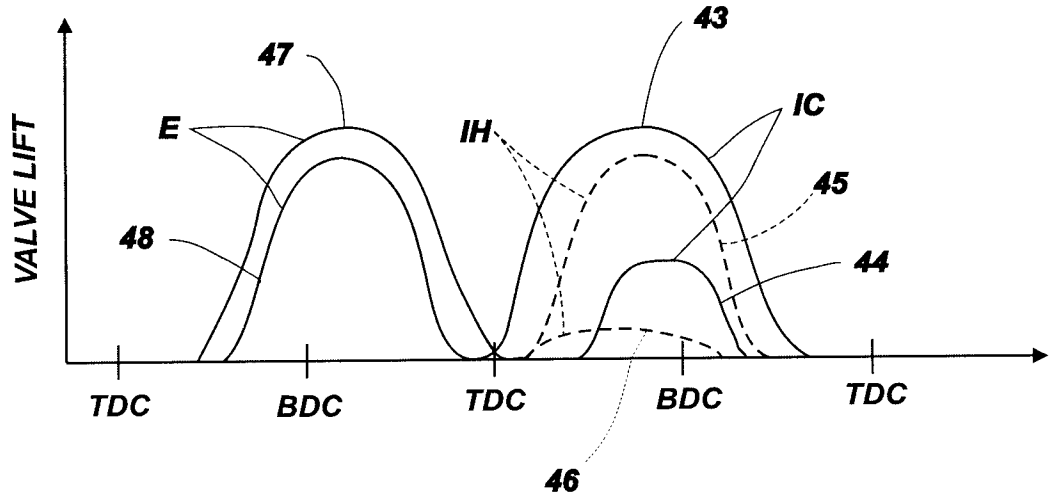

28
24
27
35
CPS
IC
E
23
CPS
37
CPS
IH
E
27
26

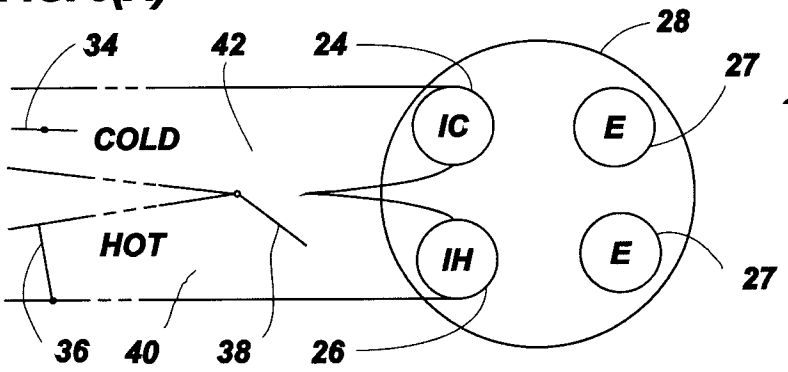
FIG. 8(B)


43
47
IC
E
IH
45
48
44
VALVE LIFT
TDC
BDC
TDC
BDC
TDC
46

LIFT PROFILE	EVENT LENGTH (CAD)	NORMALIZED VALVE MAX. LIFT	VALVE OPEN TIMING	VALVE CLOSE TIMING
INTAKE IC-OUTER	280 ~ 320	1	0 ~ 15 CAD BTDC	95 ~ 125 CAD ABDC
INTAKE IC-INNER	150 ~ 210	0.3 ~ 0.7	-50 ~ 0 CAD BTDC	25 ~ 45 CAD ABDC
INTAKE IH-OUTER	170 ~ 210	0.8 ~ 0.95	-35 ~ 0 CAD BTDC	25 ~ 45 CAD ABDC
INTAKE IH-INNER	< 180	< 0.2	-60 ~ 25 CAD BTDC	0 ~ 25 CAD ABDC
EXHAUST E-OUTER	230 ~ 250	1	50 ~ 70 CAD BBDC	0 ~ 20 CAD ATDC
EXHAUST E-OUTER	190 ~ 220	0.8 ~ 0.95	40 ~ 60 CAD BBDC	-35~ 0 CAD ATDC

FIG. 8(C)

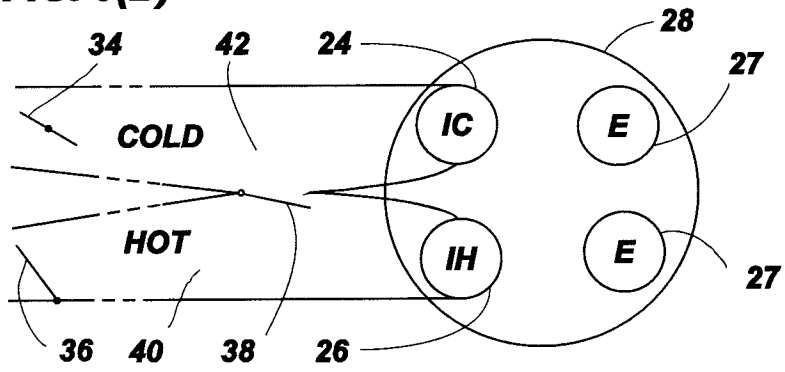
FIG. 9(A)



SI MODE

IC	OUTER PROFILE
IH	OUTER PROFILE
E	OUTER PROFILE

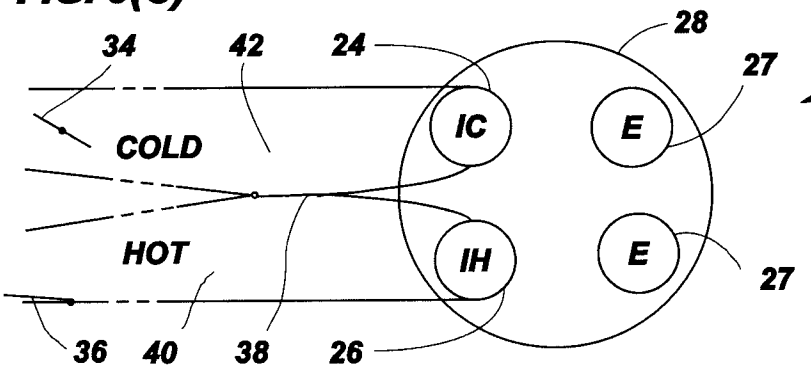
FIG. 9(B)



SI MODE

IC	OUTER PROFILE
IH	INNER PROFILE
E	OUTER PROFILE

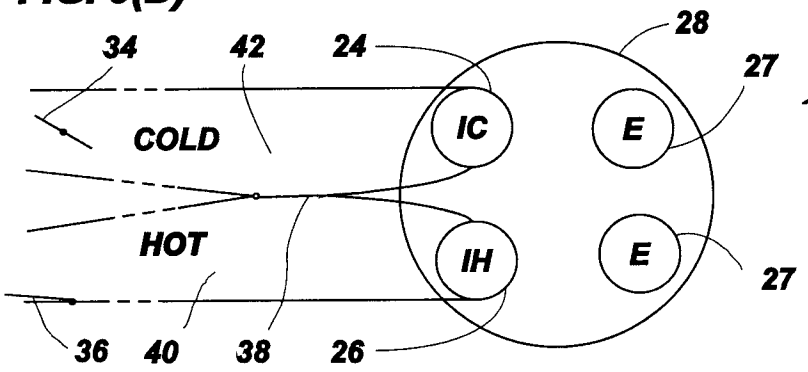
FIG. 9(C)



SI MODE

IC	OUTER PROFILE
IH	INNER PROFILE
E	OUTER PROFILE

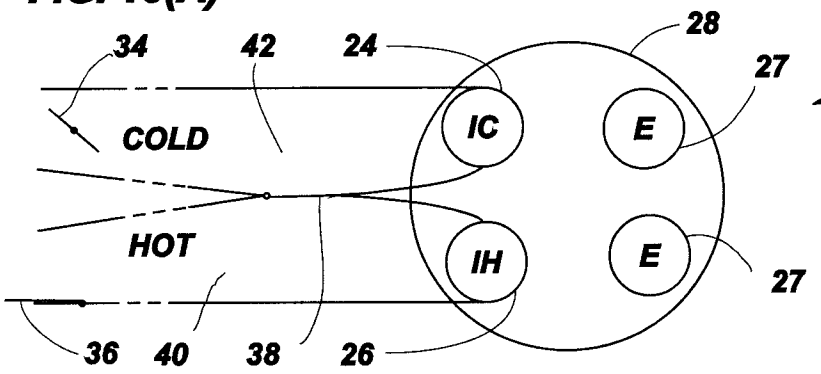
FIG. 9(D)



HCCI MODE

IC	INNER PROFILE
IH	OUTER PROFILE
E	INNER PROFILE

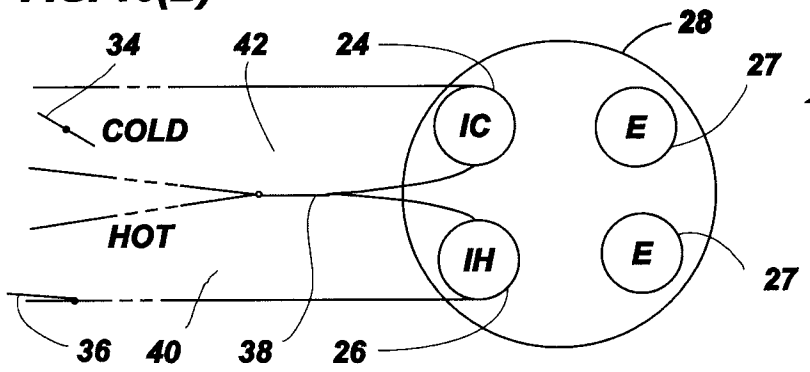
FIG. 10(A)



HCCI MODE

IC	OUTER PROFILE
IH	OUTER PROFILE
E	OUTER PROFILE

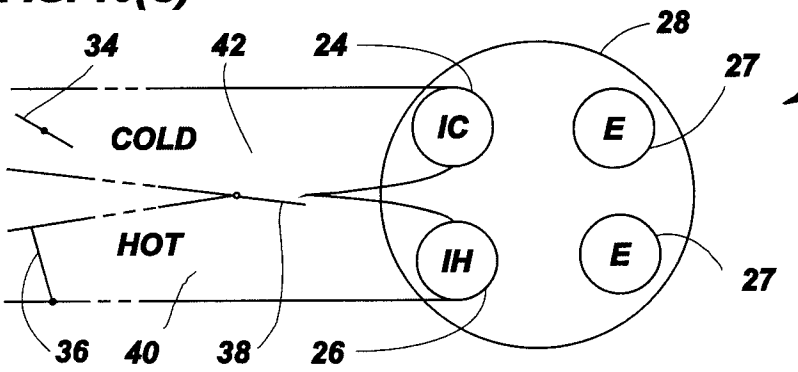
FIG. 10(B)



SI MODE

IC	OUTER PROFILE
IH	INNER PROFILE
E	OUTER PROFILE

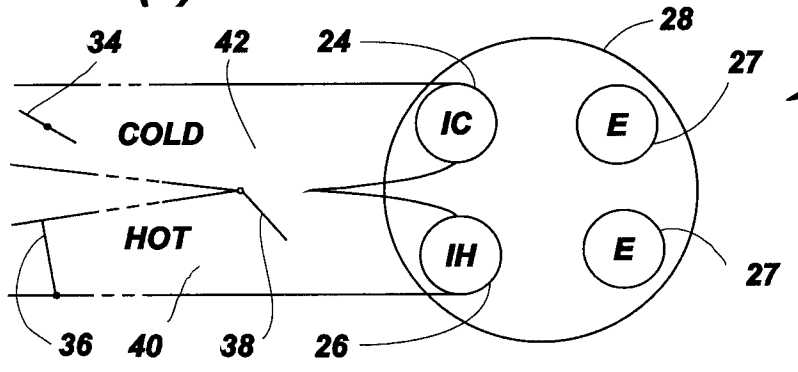
FIG. 10(C)



SI MODE

IC	OUTER PROFILE
IH	INNER PROFILE
E	OUTER PROFILE

FIG. 10(D)



SI MODE

IC	INNER PROFILE
IH	OUTER PROFILE
E	INNER PROFILE

FIG. 11

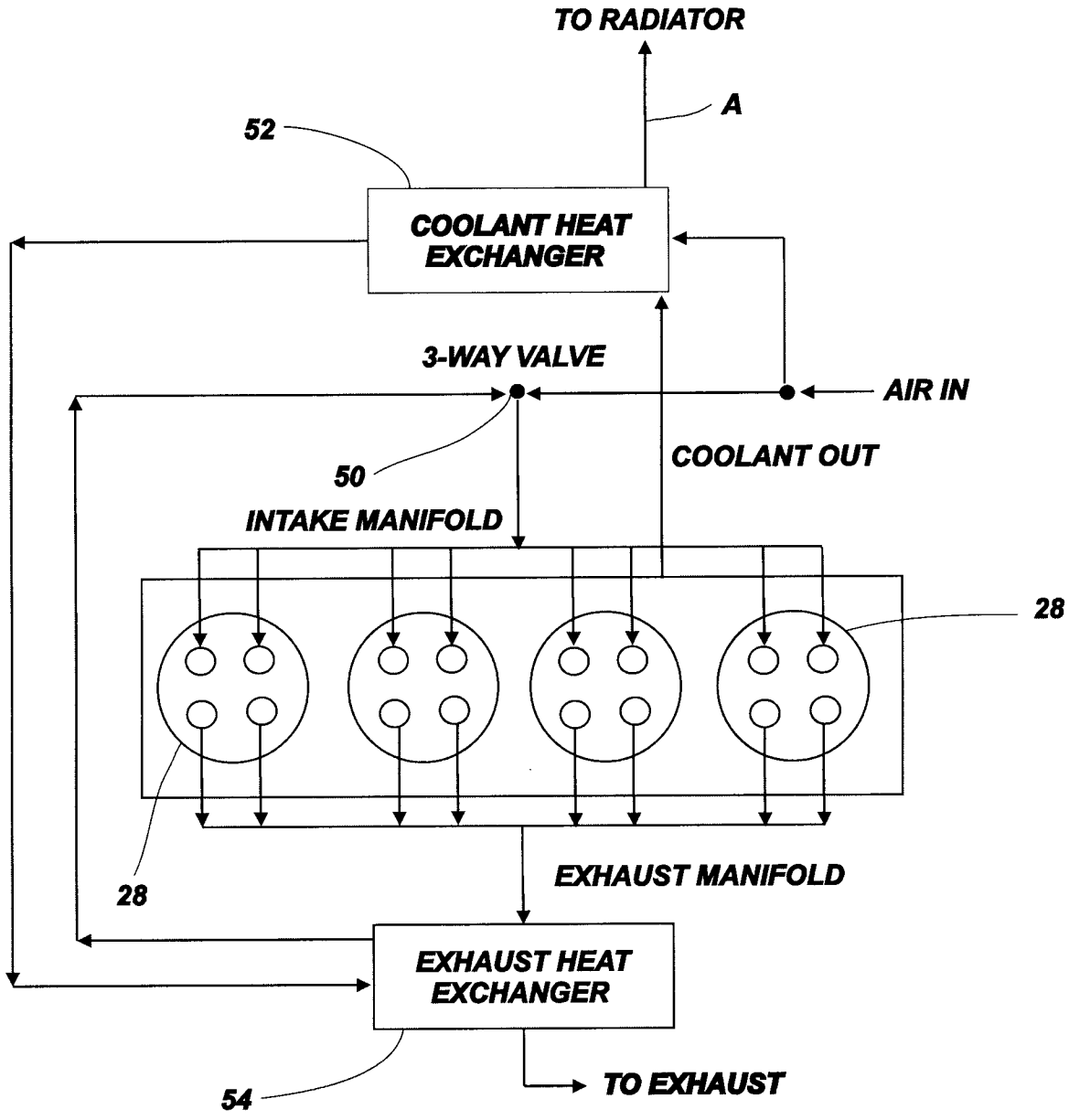

TO RADIATOR
A
52
COOLANT HEAT EXCHANGER
3-WAY VALVE
AIR IN
50
COOLANT OUT
INTAKE MANIFOLD
28
28
EXHAUST MANIFOLD
EXHAUST HEAT EXCHANGER
54
TO EXHAUST

FIG. 12

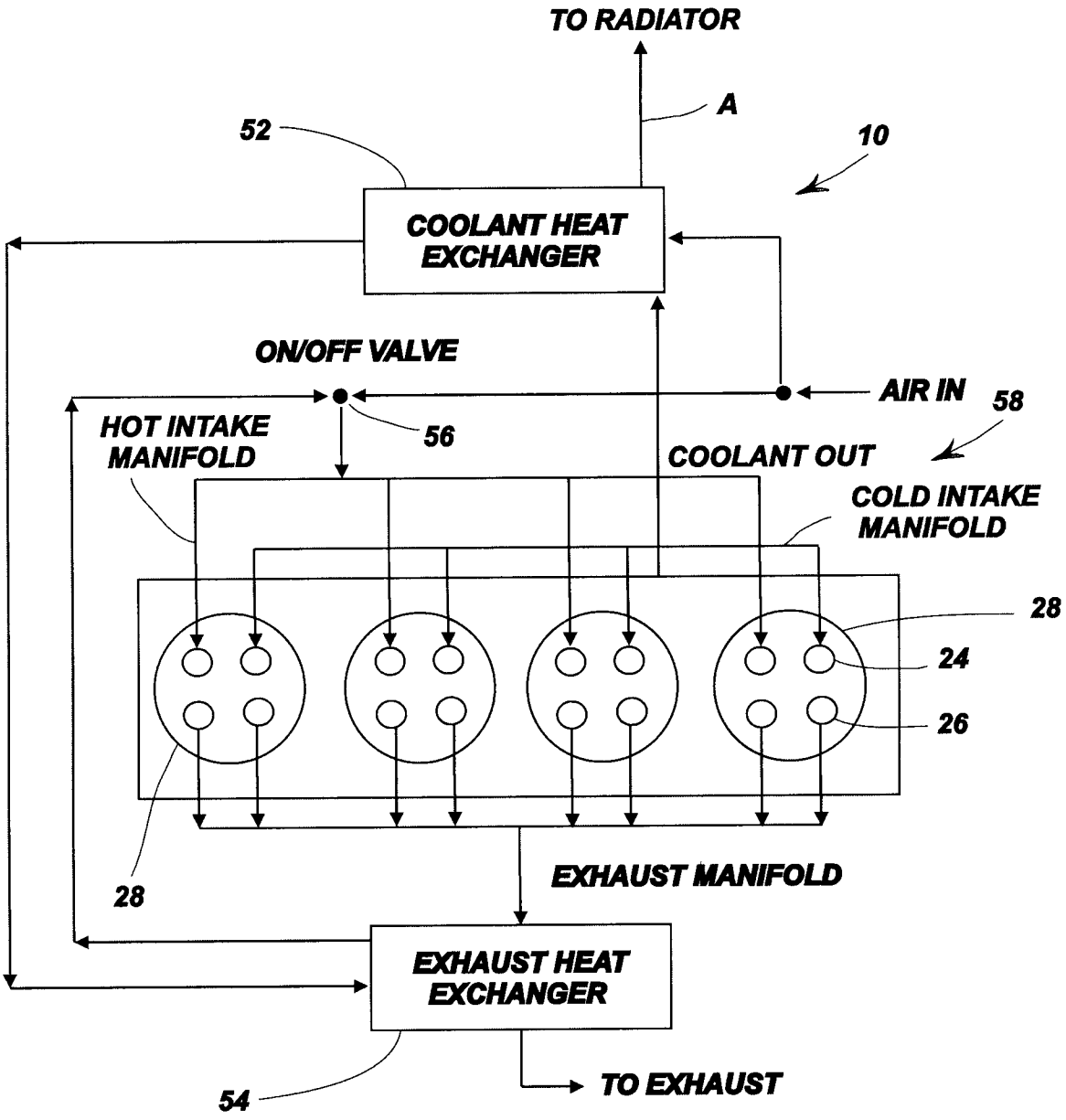

TO RADIATOR
A
52
10
COOLANT HEAT EXCHANGER
ON/OFF VALVE
AIR IN
58
HOT INTAKE MANIFOLD
56
COOLANT OUT
COLD INTAKE MANIFOLD
28
24
26
28
EXHAUST MANIFOLD
EXHAUST HEAT EXCHANGER
54
TO EXHAUST

FIG. 13

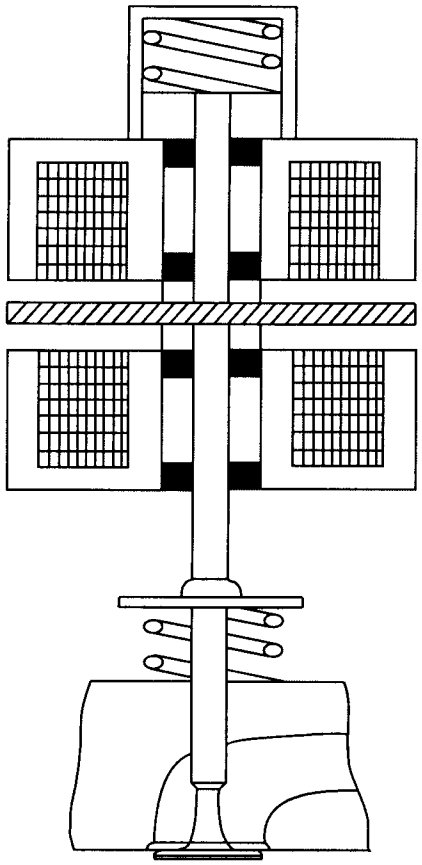


FIG. 14

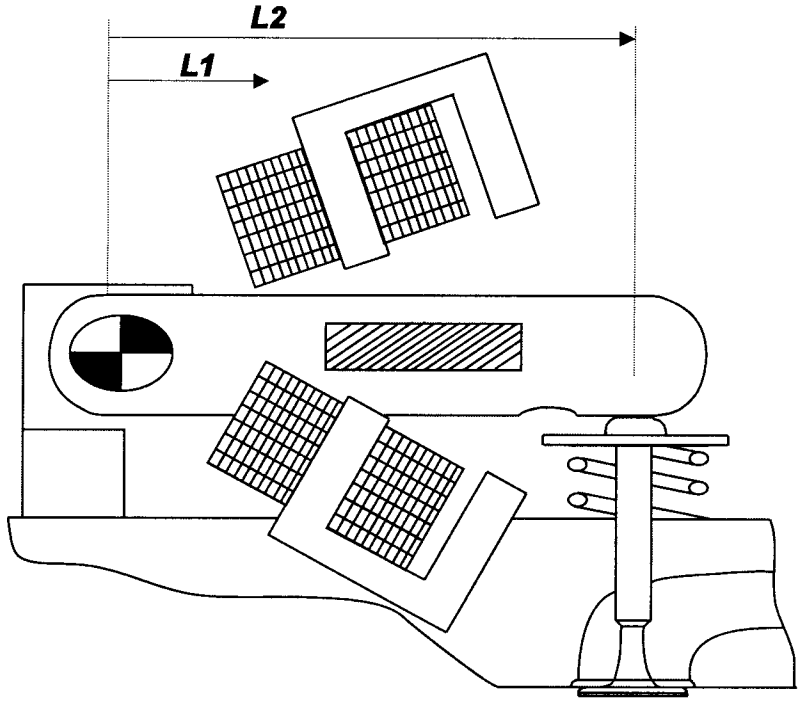
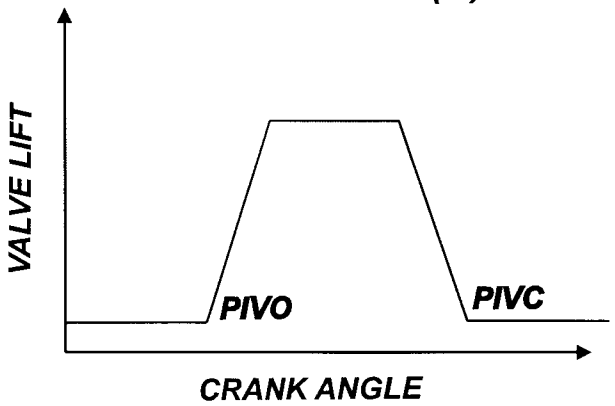
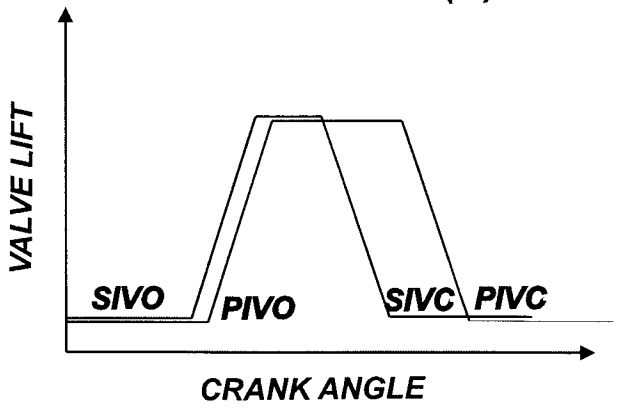


FIG. 15(A)



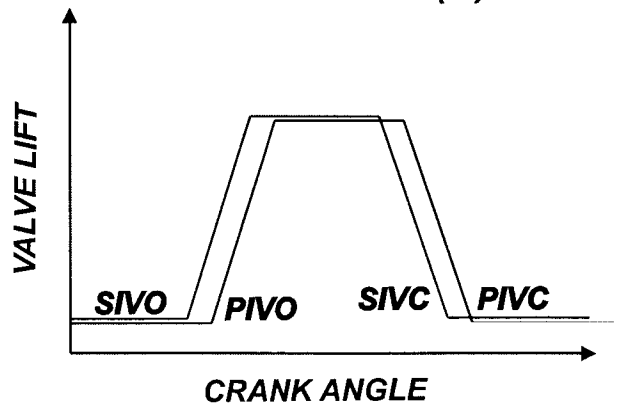
VALVE TIMINGS FOR AMBIENT INTAKE AIR TEMP; SECONDARY INTAKE VALVES DO NOT OPEN (FULL COLD)

FIG. 15(B)



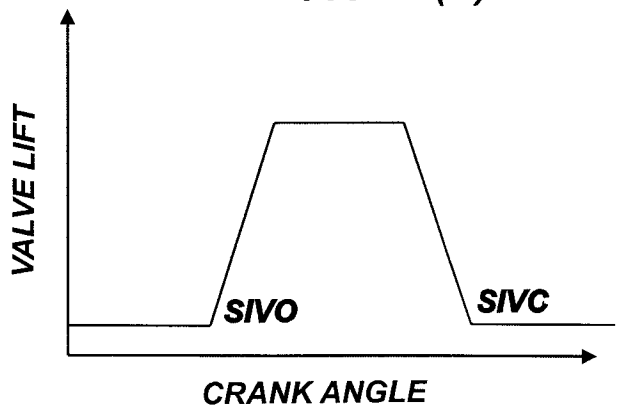
VALVE TIMINGS FOR 80 DEG C INTAKE AIR TEMP (WARM)

FIG. 15(C)



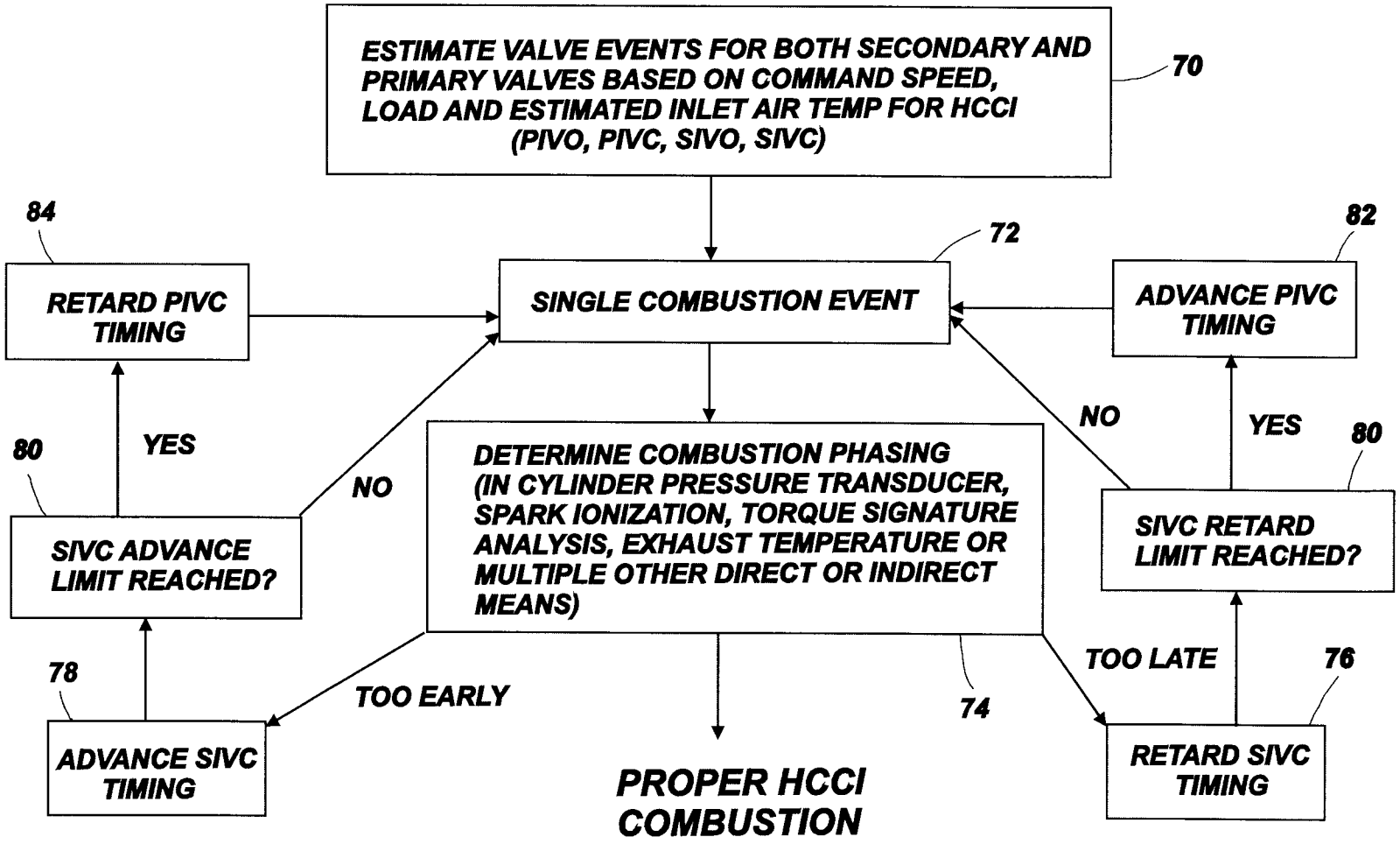
VALVE TIMINGS FOR 120 DEG C INTAKE AIR TEMP (WARMER)

FIG. 15(D)



VALVE TIMINGS FOR 180 DEG C INTAKE AIR TEMP; PRIMARY INTAKE VALVES DO NOT OPEN (FULL HOT)

FIG. 16


ESTIMATE VALVE EVENTS FOR BOTH SECONDARY AND PRIMARY VALVES BASED ON COMMAND SPEED, LOAD AND ESTIMATED INLET AIR TEMP FOR HCCI (PIVO, PIVC, SIVO, SIVC)
70
84
RETARD PIVC TIMING
72
SINGLE COMBUSTION EVENT
82
ADVANCE PIVC TIMING
80
YES
NO
DETERMINE COMBUSTION PHASING (IN CYLINDER PRESSURE TRANSDUCER, SPARK IONIZATION, TORQUE SIGNATURE ANALYSIS, EXHAUST TEMPERATURE OR MULTIPLE OTHER DIRECT OR INDIRECT MEANS)
NO
YES
80
SIVC ADVANCE LIMIT REACHED?
SIVC RETARD LIMIT REACHED?
78
TOO EARLY
TOO LATE
76
74
ADVANCE SIVC TIMING
PROPER HCCI COMBUSTION
RETARD SIVC TIMING